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TROPICAL CYCLONE ACTIVITY IN A WARMER CLIMATE AS SIMULATED BY A HIGH_RESOLUTION COUPLED GENERAL CIRCULATION MODEL: CHANGES IN FREQUENCY AND AIR-SEA INTERACTION

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ABSTRACT

This study investigates the possible changes that the greenhouse global warming might generate in the characteristics of the tropical cyclones (TCs) (Gualdi et al. 2008). **The analysis has been performed using climate scenario simulations** (fig. 3) **carried out with a fully coupled high–resolution global general circulation model** (**INGV-SXG**, fig. 1, Gualdi et al. 2008). The capability of the model to reproduce a reasonably realistic TC climatology has been assessed by comparing the model results from a simulation of the XX Century (fig. 2) with observations (NHC, JTWC). The TC detection method is based on Bengtsson et al. 1995 and Walsh et al. 1997. The model appears to be able to simulate tropical cyclone-like vortices with many features similar to the observed TCs (fig. 6). The simulated TC activity exhibits realistic geographical distribution (fig. 4), seasonal modulation (fig. 5) and interannual variability, suggesting that the model is able to reproduce the major basic mechanisms that link the TC occurrence with the large scale circulation. **The results from the climate scenarios reveal a substantial general reduction of the TC frequency** (fig. 7) **when the atmospheric CO_2 concentration is doubled and quadrupled** (fig. 3)**. The reduction appears particularly evident for the tropical north west Pacific (WNP) and north Atlantic (ATL)**. In the WNP the weaker TC activity seems to be associated with a reduced amount of convective instabilities (fig. 9 and tab. 1). In the ATL region the weaker TC activity seems to be due to both the **increased stability of the atmosphere and a stronger vertical wind shear**. Despite the generally reduced TC activity (fig. 7), **there is evidence of increased rainfall associated with the simulated cyclones** (fig. 8). Using the new fully coupled CMCC model (CMCC_MED), with a T159 (~80 Km) atmospheric resolution, we found a significant modulation of the Ocean Heat Transport (OHT) induced by the TC activity.

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The INGV-SXG Fully Coupled Model

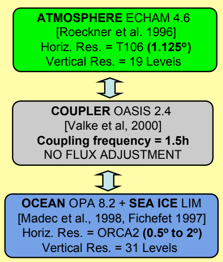


Fig. 1 The INGV-SXG Fully Coupled Model components .

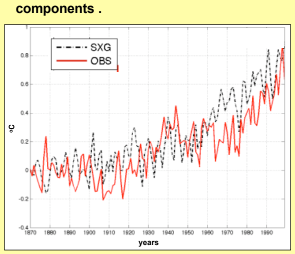


Fig. 2 The XX century (20c3m) Global Mean simulated Surface Temperature Anomaly (black) in comparison with observations (red) [Jones et al., 2001].

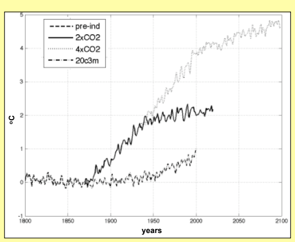


Fig. 3 Global Mean Simulated Surface Temperature Anomaly in preindustrial (PREIND), XX Century (20c3m), CO_2 doubling (2xCO2) and CO_2 quadrupling (4xCO2) experiments.

Simulation of Tropical Cyclones in INGV-SXG

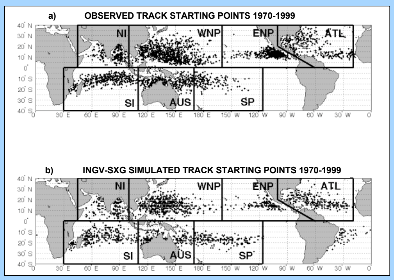


Fig. 4 Observed (a) and simulated (b) TCs track starting point during the period 1970-1999.

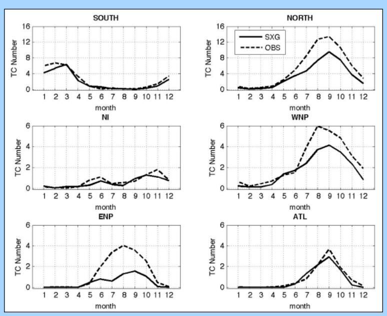
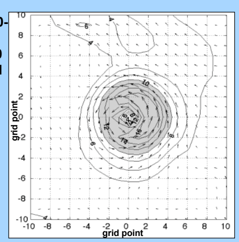


Fig. 5 Seasonal modulation of the TC occurrence in INGV-SXG (solid) and observations (dashed).

Fig. 6 Composite of 850-hPa wind [m/s], associated with the 100 most intense simulated WNP 20c3m TCs.

1 grid point ~= 120 Km.



TC Activity in a Warmer Climate

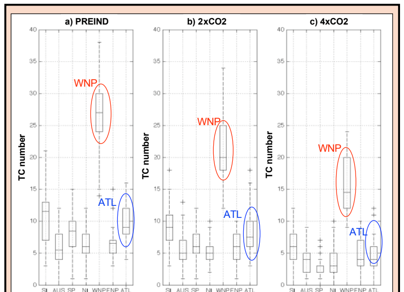


Fig. 7 Box plots of the number of TCs per year in INGV-SXG simulations: preindustrial (a), CO_2 doubling (b) and CO_2 quadrupling (c) experiments.

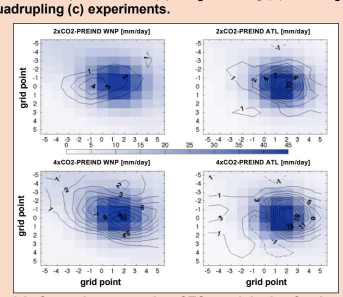


Fig. 8 Left panels: composite of TC precipitation for the PREIND experiment over the WNP region (shaded) along with the difference 2xCO2-PREIND (upper panel) and 4xCO2-PREIND (lower panel) shown by the contour patterns. The composites represent the mean rainfall rate averaged over the TCs life time. Right panels: as for the left panels but for ATL.

	PREIND	2xCO2	4xCO2
CAPE Tropical Mean [J/Kg]	109.09	131.39 (+20%)	135.24 (+24%)
CAPE Tropical Oceans only [J/Kg]	132.41	155.21 (+17%)	152.40 (+15%)
CIN Tropical Mean [J/Kg]	13.06	16.04 (+23%)	18.73 (+43%)
CIN Tropical ocean only [J/Kg]	8.16	9.85 (+21%)	11.46 (+40%)

Tab. 1 Spatial average of mean convective available potential energy (CAPE) and mean convective inhibition (CIN). The mean CAPE and CIN are obtained by averaging over the 30-year periods of the PREIND, 2xCO2 and 4xCO2 experiments.

Tropical Cyclone induced Air-Sea Interaction as represented by CMCC_MED model

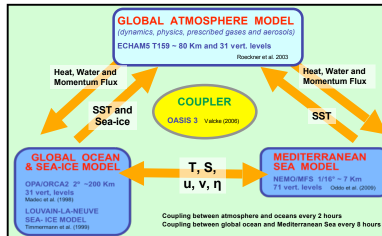


Fig. 10 CMCC_MED, a fully coupled 3 component model.

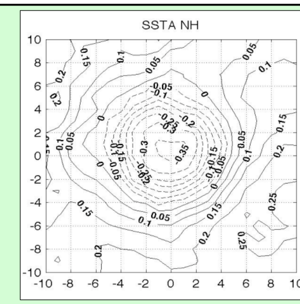


Fig. 11 Composite patterns of Sea Surface Temperature Anomaly (SSTA) over the TC eye region computed as the difference between the SST at T=T_WIMAX+2days and the SST 6 hours before T_WIMAX, where T_WIMAX is the time at which maximum 10m wind velocity is reached during the TC evolution. The SSTs used to compute the anomaly are 6 hourly averaged fields. The anomaly is computed over the 100 most intense TCs of the NH during 1970:1999. SSTA units are Celsius degrees. x and y axes are model grid points (distance between two grid points ~ 80 Km) from the TC core.

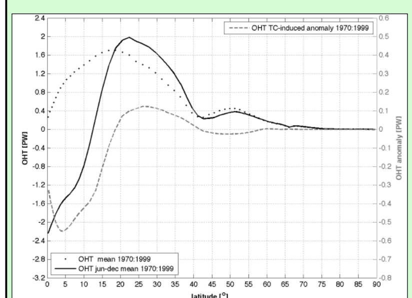


Fig. 12 Northern Hemisphere Ocean Heat Transport (dot and solid lines: respectively annual and Jun-Dec mean) and Northern Hemisphere Ocean Heat Transport Anomaly induced by TCs (dashed line). Black dotted line is the annual mean OHT over the period 1970:1999. Black solid line is the June-December mean OHT over the period 1970:1999. Gray dashed line is the mean anomaly induced by the 100 most intense NH TCs over the period 1970:1999. The anomalies have been computed for 20 days around the day of maximum intensity (T_WIMAX ±10dd) of the TC with respect to the climatological (1970:1990) relative month.

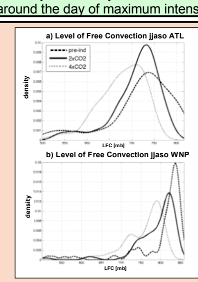


Fig. 9 Probability distribution function(PDF) of the Level of Free Convection (LFC,[mb]) for PREIND (dashed), 2xCO2 (solid) and 4xCO2 (dotted) exp. over the ATL (a) and WNP (b) region during JJASO. On the x axis the value of vertical levels in Millibar (mb),and on the y axis the (density of) frequency of occurrence at which free convection can be triggered at that level.

Conclusions

- General reduction of TCs frequency (fig. 7) when atmospheric CO_2 concentration is doubled (2xCO2) and quadrupled (4xCO2) (fig 3) with respect to preindustrial value (PREIND).
- Reduced amount of convective instabilities (fig 9, tab. 1) in 2xCO2 and 4xCO2 experiments with respect to PREIND.
- CMCC_MED CGCM at 80 Km of atmospheric resolution is capable to detect the tropical cyclone - ocean interaction in terms of induced SST cooling (fig. 11). Model results suggest that TCs affect significantly the Meridional Ocean Heat Transport (fig. 12).